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AN ASSESSMENT OF SCIENCE AND TECHNOLOGY PARKS: TOWARDS A BETTER UNDERSTANDING OF THEIR ROLE IN THE EMERGENCE OF NEW TECHNOLOGIES

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Abstract

This papers examines the role of science and technology parks in fostering the emergence of new technologies. The first part of the paper tries to explain the development of science parks against the context of scholarly work in the area of the management of technology. The second part then provides empirical data collected among Belgian and Dutch science park firms.

The last and final part of the paper discusses the not too optimistic results and tries to change the focus from the 'miniature' R&D network which might develop on science parks to the 'R&D community' network which unites all researchers working on a particular, interrelated set of scientific and technological problems. Furthermore, it is argued that a unified theory of technological emergence is badly needed. Only if the dynamics behind the development of a new technology are unravelled can technology policies, such as the ones involving the creation of science parks, be targetted more effectively.

An assessment of science and technology parks: towards a better understanding of their role in the emergence of new technologies

1. Introduction

Governments, universities as well as industry have engaged in a wide spectrum of organizational experiments aimed at strengthening the links between the academic and the industrial environment. The primary idea behind those policy measures is to foster the link between science and technology. The need to bridge the gap between *academic science* and *industrial technology* stems from the belief that science and technology are two different worlds, often incompatible with one another. This view of incompatibility has gained widespread acceptance among scholars and policy makers. Technology is local, confined to the boundaries of the firm, and is viewed as an important competitive asset. Science, on the other hand is universal, free to everyone. This fundamental difference between both worlds calls for appropriate technology transfer mechanisms. Science and technology parks are just one of them. Although they have received above average attention in technology policy during the last two decades, recent criticisms have started to question their relevance as technology transfer mechanisms.

The aim of this paper is threefold. First, we want to provide some theoretical background against which the benefits and problems facing science parks as a technology transfer mechanism might be explained. Second, empirical data from a survey of Belgian and Dutch science park firms are used to illustrate some of the points discussed in the first part of the paper. Third, we would like to propose an approach towards a unified theory of technological emergence which may enhance our understanding of the technology transfer process in general. Finally, the implications of such a broader framework will be discussed within the context of the development of science and technology parks. More specifically, this discussion will focus on the role of networking in promoting technical change. A study of networks of technical change is believed to offer a viable alternative in which the market-like world of science and the hierarchical world of technology blend together.

2. The emergence of science parks: a contextual explanation

Technology has acquired its proper place in the arena of strategic variables and is nowadays considered to be one of the principal drivers of competition: "Technological change is the great equalizer, eroding the competitive advantage of even well-entrenched firms and propelling others to the forefront." (Porter, 1985). As a consequence, technological innovation should be approached as a corporate-wide task, beyond the realm of R&D-management (Rothwell 1977). Recognition of the strategic importance of technology in the modern corporation not only leads to an emphasis on effective intracompany cooperations and communications. Boundaries between the organization and its environment are also fading. Finding the proper balance between cooperation and competition, between internal versus external technology development, has become an important issue (Friar and Horwitch, 1986).

Together with the growing awareness of the importance of extra-organizational scientific and technological linkages, the belief that universities constitute a significant *underutilized* source of technological innovation has gained wide acceptance. For instance, a National Science Foundation study (1982) states that "direct links between universities and corporations currently constitute only a miniscule portion (less than one-half of one percent) of the national R&D-effort." Despite these realities, there exists a firm belief that universities could play a crucial role in promoting technological change. First of all, they make their contributions *indirectly* by advancing the frontiers of science, by critically reviewing and systematizing the accumulated technical knowledge, and, especially through the training of students and researchers. But, at the same time, universities can be viewed as pools of technical expertise and creativity to be tapped *directly* through the involvement of academic scientists and engineers in the process of industrial innovation. Stankiewicz (1984) demonstrates that the emphasis on such direct links is intensifying. Although several barriers between academia and the private sector may still exist, awareness of possible complementarities grows steadily.

One experiment to alleviate those barriers has been the creation of science and technology parks. According to the United Kingdom Science Park Association, a Science Park is a property based initiative which includes the following features:

- Has formal and operational links with a University, other Higher Education Institution or Research Center;
- Is designed to encourage the formation and growth of knowledge-based businesses and other organizations normally resident on site;
- Has a management function which is actively engaged in the transfer of technology and business skills to the organizations on site. (Monck et al., 1988)

This definition reflects the concern of universities and other technical institutions to encourage the transfer of technology and business skills among the tenants of the park. It thus excludes those instances where there is no organizational commitment to stimulate or facilitate access to technology. Belgian and Dutch science parks, which are the focus of the empirical data reported in this paper, undoubtedly conform to the above definition.

But in order to sketch a contextual framework against which the emergence of science parks can be explained, it is not enough to point to the importance of multiple R&D information sourcing as part of modern technology strategy. Nor is it sufficient to believe that universities are underutilized sources of technological innovations. Indeed, science parks are only one particular mechanism to stimulate technology transfers between industry and academia. Multiple other mechanisms exist, such as research consortia, joint ventures etc. A third important stimulus to create university science parks all around the western world have been the role models provided by Silicon Valley, Route 128, and the Cambridge Phenomenon in the UK (Dorfman, 1983; Segal et al., 1985; Lampe, 1988). Those examples have led to attempts to imitate the emergence of high-technology clusters. To summarize, Dorfman (1983) provides us with three groups of factors which made Massachusetts' high-tech boom possible: the presence of physical resources (labor

supply; technological infrastructure; venture capital; relatively low cost, good surface; air transportation; attractive residential neighbourhoods with easy access to work sites), external economies of scale, and the new firm entrepreneurialism. This convinced many regional development planners that a scenario existed to create regional entrepreneurial technology clusters. The local university would act as a growth pole, being a locus of high technology information to established industrial firms and, at the same time, being a source of new technology based firms. The presence of a science park should facilitate the transition of academic scientists to become academic entrepreneurs. Physical proximity would ease the flow of scientific/technological information and the creation of a network of collaborations among different science park tenants. Resident companies would gain privileged access to highly specialized manpower in the form of graduate students and university researchers. Thus, one of the *fundamental premises* in the justification for the growing number of science parks is that high-technology industry benefits from its location alongside a university because of the enhanced information, collaboration and recruitment opportunities (Stankiewicz, 1984; Nicholls, 1986; Sunman, 1986; Monck et al., 1988).

3. From enthusiasm to scepticism?

Given this context, the enthusiasm of government planners, university officials and industrialists with respect to the creation of science parks is not astonishing. There are now more than 150 US science parks (Engström, 1987). In 1988, the UK had 38 operational parks and 9 more were planned (Financial Times, 11/11/1988). Belgium has 10 university science parks, the Netherlands 3. The number of German science parks increases steadily. France created giant development schemes, such as Sophia Antipolis near Nice. Japan started creating several "Technopoleis", e.g. Tsukuba. The list is still growing and this growth is not likely to come to an end in the near future.

Notwithstanding this enthusiasm, research studies remain sceptic. The NSF-study on university-industry relationships (1982) found that over 50 percent of the US-parks never approached their initial expectations and that they are generally not significant stimuli to technology transfer. Miller and Côté (1987) reach the same conclusion in their recent book, "Growing the Next Silicon Valley". Macdonald (1987) pretends that much of the enthusiasm surrounding British science parks is a product of self-interest and is in stark contrast to the (dark) reality that will eventually face many of them. Monck et al. (1988) concluded their recent survey (sponsored by the UK-Science Park Association) with the following statement: "These results suggest the need to reappraise the comparative advantage of a science park location. They indicate two alternatives. The first is that less emphasis should be placed upon direct or indirect links with the local university, since that can apparently be cultivated by firms located elsewhere. Alternatively, the results indicate that the level of university linkage developed by off-park firms has not significantly been bettered by science park firms."

One drawback of some of those research studies is a lack of empirical data to support their scepticism. However, the divergent opinions surrounding the impact of science and technology parks warrant further empirical research. This then is a major objective of this paper.

4. Science parks: a theoretical evaluation

4.1. Interorganizational R&D-linkages

Recent research on corporate technology strategy points to the importance of external R&D linkages (Fusfeld, 1985; Perlmutter and Heenan, 1986). Haklisch's systematic review of technical alliances in the semiconducter industry (1986) shows that such collaborations are not confined to a specific geographical context. Daly (1985) demonstrates the same world-wide network of R&D cooperations and information flows in his strategic analysis of the biotechnology industry. Thus, the explanation of science park advocates that geographical proximity will stimulate

interorganizational information networks among science park occupants may be based on a biased understanding of the relation between physical distance and communication. This can be explained by the fact that person-to-person networks basically are of two types: spatial and professional. Spatial networks are based on a social and/or physical proximity such as exists within the industrial research laboratories studied by Allen (1984). Professional networks are networks such as the classical invisible college of academic science which links specialists of a particular discipline or profession and have no boundaries per se. Some professional networks are also spatial. Silicon Valley is a leading center of microchip design. With such centers one must stay in touch. Those in the same profession but located elsewhere must still be part of the spatial professional network of such centers and hence must by frequent contact maintain this membership. The professional network has no specific geographical boundaries. What really matters is to become part of the broader professional community. This professional community unites all researchers working on a related set of scientific/technological problems, whether they reside in university, industry or government laboratories.

Social proximity is yet another factor which may override geographical proximity. Corsten (1985) found that a majority of the companies in his sample contacted a particular university because either *(1)* graduates of that particular university worked at that company (44 percent) or *(2)* company respresentatives knew university scientists from contacts at conferences or seminars (23 percent). Thus, one can wonder whether the justifications given for the stimulation of science parks are over-emphasizing the benefits of geographical proximity to the neglect of professional and/or social proximity variables. Although these three types of proximity variables can occur simultaneously, this need not be the case. The information networks relevant to science park tenants can certainly not be limited to the science park environment. We will come back to this issue in the discussion section of this paper.

4.2. The interaction between science and technology

According to Price (1965) science and technology each have their own, separate cumulating structures. Only in special and dramatic cases involving the breakdown of a paradigm (Kuhn,1970; Dosi, 1982) can there be a direct flow from the research front of science to that of technology or vice versa. Allen (1984) basically agrees with this point of view, although he recognizes the possibility of a gap-filling science: "Occasionally, technology is forced to forfeit some of its independence. This happens when its advance is impeded by a lack of understanding of the scientific basis of the phenomena with which it is dealing. The call then goes out for help." This call for help may cause a temporary, intense interaction between science and technology. Another remark on Price's thesis is that nowadays, technologies have emerged (e.g. biotechnology, artificial intelligence) which are much more rooted into academic science. However, even if one accepts the notion of "technoscience" (Latour, 1987), pointing to a complex blending of the worlds of science and technology (often in the minds of the individual scientists and technologists themselves), it is questionable whether a science park is the right locus to achieve this blending: "The notion that *any single* university department contains even all the technical information required by a high-technology firm, while evident in much of the justification given for science parks, would alarm most academics. Only a weak department can pretend to be self-contained: the strongest department is more likely to be but a node of an academic information network to which high-technology firms may seek access." (Macdonald, 1987).

Finally, when referring to the science/technology interactions occurring in Silicon Valley or along Route 128, Dorfman (1983) reminds us that "the academic institutions that provided much of the momentum are steeped in a tradition of research at the frontiers of developments in electronics, computer science and instrumentation and compete with a handful of other universities for top ranking in graduate programs in these fields. It remains to be seen whether institutions of lesser rank can provide the same stimulus to innovation."

4.3. Labor supply factors

Dorfman (1983) mentioned labor supply as one of the critical factors to the Massachusetts' high-tech boom. Oakey (1981) found that labor supply was a critical location factor in British high-technology industry. Moreover, manpower flows are believed to augment organizational innovative capabilities especially in the case of radical innovations (Ettlie, 1985). This linkage between manpower flows and technological innovation certainly makes sense. Ideas have no real existence outside the minds of men. The human brain has a capacity for flexibly restructuring information in a manner that has never been approached by even the most sophisticated programs. For truly effective transfer of technical information, we must make use of this human ability to recode and restructure information so that it fits into new contexts and situations. Consequently, the best way to transfer technical information is to move a human carrier (Allen, 1984). How might a science park location affect a firm's labor supply patterns?

First of all, the symbiosis of university and industry is believed to enhance recruitment opportunities for industrial R&D. Through collaborations with academia, industry gains access to high-talented engineers and scientists. Recent studies on manpower flows in AI (Van Dierdonck and Van der Poorten, 1987), and biotechnology (Faulkner, 1986), show the omni-presence of manpower flows between academic and industrial R&D-laboratories in nascent, science-based industries. However, when focusing on science parks, Sirbu et al. (1976) found that "virtually no interchange of personnel was reported between government laboratories and industry at any of the sites. There is a modest flow of personnel from university laboratories to industry, but very little in the reverse direction." As far as the recruitment of university graduates is concerned, those authors reached the following conclusions: "Most of the US firms we interviewed recruited on a nationwide basis and none felt they drew disproportionally from local universities. They reported hiring 16.5% of their staff on average from local schools." Monck et al. (1988), in their study of British science parks, were also unable to detect significant differences in recruitment patterns between off-park

and on-park companies. Findings as these suggest rather sharp differences between the average university science park and the successful high-technology sites of Route 128, Silicon Valley and Cambridge-UK (Dorfman,1983; Segal et al., 1985).

A second aspect are the academic new venture companies. Science parks are believed to stimulate academic entrepreneurship (Monck and Segal, 1983; Stankiewicz, 1984). Roberts and Wainer (1968, 1971, 1988) provide us with an overwhelming database of MIT-entrepreneurs who clustered around Route 128. Segal et al. (1985) identified a family tree of 244 companies which directly or indirectly originated from 14 Cambridge University departments. However, when referring to those success stories, a few remarks should be kept in mind. First of all, in none of these two examples is there a clear proof that a local science park enhanced this spin-off phenomenon. Even in the case of Stanford Industrial park, not everyone agrees on its relationship to the high-tech spin-off phenomenon of Silicon Valley: "While the University certainly did establish the park, it did so primarily because the industrial growth of the region had increased Leland Stanford's bequest so much that the University could no longer afford its retention as farmland. Unable to sell the land, the University was forced to make it pay for itself. Stanford Industrial Park is very much the product of Silicon Valley's industrial prosperity rather than vice versa." (Macdonald, 1987). Second, although more and more universities acknowledge the potential of spin-offs as a technology transfer mechanism, academic entrepreneurs are still the exception rather than the rule at most academic institutions. Miller and Côté (1987) suggest that a majority of science parks have not been able to stimulate massive spin-off creation. At the time of their study, Sirbu et al. (1976) identified only one spin-off on Research Triangle Park-North Carolina. To summarize, although it may be advantageous to an academic spin-off to locate on a science park (since the entrepreneurs then remain close to their nucleus) the extent as to which this happens in reality is rather ambiguous. The recent study of British science parks by Monck et al. (1988) suggests a similar ambiguity.

Third, it is often argued that proximity to a university offers opportunities for continuing education of company staff (Sirbu et al., 1976). Participation in such programs on behalf of science park tenants might offer a first step in forging more intense links between organizations on the park (including the university). Indeed, it is often argued that informal linkages are a first and a highly necessary step in establishing more formalized R&D collaborations (Stankiewicz, 1984; Faulkner, 1986): participation in continuing education programs may thus influence the social proximity factor discussed earlier. However, even when a technical/social network of contacts among science park occupants should occur, Macdonald (1987) suggests that it will only be a "miniature network" in comparison to the global scientific and technological network relevant to the different science park tenants. In this respect, it is also interesting to recall Sirbu et al.'s (1976) conclusion concerning consulting arrangements between science park tenants and the local university: "Local universities also played minor roles as sources of consultants or staff members: 70 percent of the firms we interviewed did not use any university consultant. Consultants, as we were told, and has been noted by other researchers, were drawn from whatever university had the best people in the particular field of interest to the firm. "

4.4. Other advantages of a science park location

Dorfman (1983) refers to agglomeration externalities as another advantage of a high-technology cluster location. For some firms in some industries and at some stages of development there are indeed important advantages to locate near to complementary and competitive enterprises as well as to customers. Segal et al. (1985) reach the same conclusion in their study of the Cambridge Phenomenon. However, when considering Silicon Valley, Route 128 or the Cambridge Phenomenon, we are confronted with phenomena involving a region's (multiple) universities. Typically, the new high-tech businesses became embedded in an existing business and technological infrastructure in a rather spontaneous manner. Most European (and American) science

parks, on the contrary, are rather artificially created around a single university which is then believed to act as a growth pole. They are often isolated, with little or no local business texture present. Segal et al. clearly demonstrated the role of the inner Cambridge town in the growth of the Cambridge high-tech cluster. For the majority of science parks, it is rather difficult to speak of external economies of scale. At best, one can hope that they will evolve over a longer period of time. Thus, the advantages offered by the "rich business environment on the park" (Monck, 1983) may well be an illusion.

Finally, as far as "attractive parkland surroundings", "residential neighbourhoods", "cultural amenities", and "easy access to transportation" are concerned, several authors find those factors important only up to a certain treshold level (Sirbu et al., 1976; Galbraith, 1985; Monck et al., 1988).

4.5. Conclusions

The previous discussion focused on a number of topics which may help explain the current differences between the expectations and the realities facing the development of science parks. Although it may sound rather sceptical, we should keep in mind the recent character of many science parks (a majority of them are less than 10 years old). This may necessitate a review of some of the statements made earlier as time goes by, though at least some of the problems are unlikely to change with time (e.g., the issue of professional proximity versus physical proximity). A final remark should be made for many European science parks: the short distances on the continent. Do we really need to emphasize "physical proximity" when everything is already so close?

5. Survey of Belgian and Dutch science park tenants

5.1. The sample

At the moment of the survey (fall 1988), 8 Belgian and 3 Dutch science parks were fully operational. All of them were created through government intervention. Regional Development Agencies are heavily involved in the exploitation of the parks. The role of most universities is at least a consultative one. They all assist in the screening of candidate applications, while their involvement in the daily management of the science park varies. Each science park is linked to a single university. Some universities can have up to 3 affiliated science parks. Some of the parks are adjacent to the university, others are up to 15 kilometers distant from the patronizing academic institution. Half of the science parks in the sample are less than 5 years old (table 1). As stated in section 4.5, the age of most science parks may be a biasing factor in surveys assessing their role as a technology transfer mechanism. Indeed, science park advocates claim that it may take at least a decade for a cluster to be formed. For instance, strong useful links between academia and industry develop over many years through the gradual growth of experience and trust among individuals. However, the results of this and other surveys (Sirbu et al., 1976; Monck et al., 1988) can at least provide some impressions on the potential of science parks. Moreover, there exist at the moment several science parks which are over a decade old. This makes some predictions even less ambiguous.

In the Belgian case, 15 science park tenants were not included in the sample because of their activities (hotel, garage, tennis court, university laboratories, etc.). We were only interested in companies which might somehow benefit from interactions with academia or other high-tech firms. In the course of the survey, we learned that 7 of the 137 Belgian companies had left the science park in 1988. This reduced the Belgian subset from 75 to 68 valid responses, since the companies who left the science park did not fill out the questionnaire. These 7 declared that the science park location had only been a temporary solution to them and showed a rather low commitment towards

the local science park environment. As far as the Netherlands are concerned, Twente is somewhat different from the other science parks. This science park is in fact an incubator facility: the Business Technology Center. It was established through the involvement of Control Data, a Regional Development Agency and the University of Twente. Sunman (1986) ascribes the rapid growth of BTC Twente to the commercial orientation of its founders (especially Control Data). According to the definition of the UK-Science Park Association, BTC can be considered as a science park development. However, the emphasis on being an incubator may introduce a bias in the Dutch results (e.g., companies in the incubator will usually be small). Nevertheless, in its recruitment process, BTC heavily stresses the importance of its scientific/technological environment to potential candidates.

Sites	First year of operations	Sample N	Valid responses	
Belgium				
Haasrode	1972-73	32	16	(50%)
Sart-Tilman	1976	23	8	(35%)
Louvain (LLN)	1976	34	20	(59%)
Evere	1978	28	11	(39%)
Heembeek	1980	7	6	(86%)
Anderlecht	1985	1	1	(100%)
Nivelles	1985	2	2	(100%)
Zellik	1985	10	4	(40%)
Total		137	68	(50%)
Netherlands				
Twente	1983	49	29	(59%)
Groningen	1984	9	5	(56%)
Leiden	1985	13	7	(54%)
Total		71	41	(58%)

Table 1: Sample and response rate

The questionnaires were mailed out to the general managers of the science park companies. All returned questionnaires were eventually filled out by senior managers. Thus, we can be confident that the respondents had a broad view on the companies' activities as well as on the decision to locate on the site. The results then offer a first impression of what happens on Belgian and Dutch science parks.

5.2. Company characteristics

As could be expected, most respondents became only recently located on the sites studied (table 2).

	Number of years present on the site		
	Mean	Median	Range
Belgium (n=67)	$3^{1/2}$	2	0-12
Netherlands (n=40)	$2^{1/3}$	2	0-6

Table 2: Age characteristics of tenants

Thus, although 4 Belgian science parks were created in the 1970's, their growth really started in the 80's. Only 10 respondents were established between 1976 and 1979. The take-off of Dutch science parks was much faster. The role of BTC Twente, which accounts for the majority of the Dutch sample and the Dutch respondents, is obvious here. The other Dutch sites may develop more at the rate of their Belgian counterparts. Although Belgium showed considerable enthusiasm in the early 70's, there has been a period of stagnation between 1977 and 1985. Since 1985, the interest of regional developers and universities seems to be increasing once again. The number of new tenants on Belgian sites may reflect this policy change (median age=2 years).

Total employment for the Belgian respondents (n=68) amounts to 3856. In the Dutch case this figure is 480 (n=41). In both instances, the majority of tenants is small (see table 3). Belgian

science parks, however, were able to attract some major multinational companies (mainly in the realm of electronics, informatics, and pharmaceuticals). Blue collar workers are a minority among science park employees. This is obvious since all science parks try to minimize traditional manufacturing activities. As we will see, a lot of respondents actually have production facilities, though, in terms of employment, these activities are of secondary importance. Science park authorities also appear to be rather flexible with respect to the application of the admission rules. In some instances, the policies of regional developers have aroused irritation on the academic side. Regional Development Agencies have been accused of attaching too much importance to employment statistics, to the neglect of the creation of a technology-oriented business texture.

	Belgium (n=68)	Netherlands (n=41)
Total employment		
Mean	56.7	11.7
Median	23.5	4
Range	0-380	0-50
Blue collar employment		
Mean	5.4	1.7
Median	0	0
Range	0-50	0-30

Table 3: Employment characteristics

A total of 9 companies on Dutch science parks (n=41, 22%) belong to a multinational group. This number is remarkably higher in Belgium: 33 out of 68 tenants (49%). This once again reflects the policy of Belgian science park authorities to attract foreign investments, whereas Dutch science parks are more geared towards stimulating indigeneous growth.

We further defined a spin-off as "A company created by employees who leave their employer (e.g. a university laboratory, an industrial laboratory) to start their proper firm in order to commercialize technological know-how acquired on their previous job." In the Dutch case, 15 out of 41 (37%) respondents acknowledged to be a spin-off. Six of them originated from a local university laboratory, two from another science park organization. The remaining 7 had no relationship at all with other science park tenants. In Belgium, only 11 (n=68, 16%) spin-offs were detected among the respondents. Two of them originated from the local science park university. In the remaining cases, no apparent links with another science park "parent" were found. From those results, one may conclude that Belgian science parks have not been significant spin-off generators till now. This does not mean that academic spin-offs are totally absent in Belgium (Van Dierdonck and Debackere, 1988). Only, they do not seem to have a preference for a science park location.

One should also recognize that the Belgian academic community has long been, and in some cases still is, sceptical towards academic entrepreneurs. Moreover, not all scientists display the same degree of entrepreneurial behavior (Roberts and Peters, 1981; McMullan and Melnyk, 1988). The difference between Belgium and the Netherlands concerning spin-offs may also be a reflection of the different degree of involvement on behalf of the parent university in the management of the science park. Although regional developers play a crucial role in both countries, Dutch universities pursue their consultative role in a much more active manner. In Belgium only one university has been really actively involved in the promotion and management of its science park from the very beginning. Other universities have started following this example now, after they were rather passive in the past. Although it is dangerous to draw causal inferences, it appears as if active university involvement (preferably beyond a consultative role) exerts a positive influence on the development of the science park.

Only a minority of respondents provided financial results for their science park entity. Some of them were unable to do so for various reasons (establishment on the site too recent; being part of

a larger industrial group makes it impossible to sort out the results of the science park entity; the activities of the tenant are not profit-oriented), while others were simply unwilling to provide financial information. For those who did provide financial results, we can only say that the figures provided reflect the small-sized nature of the businesses present on most science parks. This remark holds as well for sales figures provided as for R&D budgets provided.

Company activities appear to be higly diverse. Moreover, at the level of each individual science parks, they even do not always match with the university's specialization. So we have the example of a university which has a good reputation in biotechnology, while the majority of firms on its science park are well established micro-electronics firms. Moreover, the broad range of activities present on most of the parks visited makes one wonder at the effectiveness of science parks in creating an atmosphere where ideas flow freely among researchers at different organizations present on the park. It is our belief that openness is indeed beneficial to technology development. However, this openness should prevail within the community of researchers working on a certain related set of scientific and technological problems. This community is, however, not confined to the narrow geographic boundaries of a science park. Instead, it is a global phenomenon. The local environment on the science park is at best a miniscule node in the communication and collaboration network relevant to each researcher. The diversity of activities present on most science parks certainly questions their potential in bringing together a critical mass of researchers on one particular spot.

Finally, 13 Dutch respondents (32%) and 39 Belgian respondents (57%) reported to carry out internal R&D activities. Of course, the absence of internal R&D does not prevent companies from having contacts and even research contracts with the local university (cfr. infra). Small companies may actually use the local university as their 'external R&D department'. 24 Dutch respondents (59%) and 44 Belgian respondents (65%) had marketing activities on the site, while 19 Dutch respondents (46%) and 34 Belgian respondents (50%) had production activities on the site.

The presence of production activities in nearly half of the companies surveyed, and the absence of internal R&D in about half of the companies surveyed, are rather striking findings if one keeps in mind the missions of a science park.

5.3. Reasons to locate on the park

Respondents were asked to rank-order the three most important reasons for their choice to locate on the site. It is somewhat surprising that 20 Dutch (49%) and 35 Belgian (51%) do not mention the availability of external scientific/technological resources at all when discussing their location decision. About half of the survey respondents do not perceive the linkage potential with the local university and/or other high-tech neighbours as an important factor in their location decision. As is apparent from table 4, only a minority of respondents mention such factors as crucial decision variables. Only a minority of our respondents thought the nearby presence of scientific and technological resources was *the most important factor* in their location decision.

Availability of scientific/ technological resources rank-ordered as ...	Belgium (n=68)	Netherlands (n=41)
1st most important	7	8
2nd most important	14	9
3rd most important	12	4

Table 4: External scientific and technological resources and location decision

Other factors influencing the location decision were: image of the site, easy access to highways or airports, financial incentives by public agencies (tax deductions, subventions), convenience of the site, available office space and services provided to young entrepreneurs (BTC Twente, Incubator Facility Leuven), etc. Only one respondent explicitly stated that recruitment

opportunities were a motivating factor. Quite similar to the British situation, "it was the prestige and image of the site which was the most frequently mentioned factor influencing choice of location." (Monck et al., 1988).

5.4. Interorganizational linkages among respondents

5.4.1. Contacts with the local university

A total of 34 (83%) Dutch respondents and 46 (68%) Belgian respondents confirmed the existence of contacts with the local university. Table 5 summarizes the types of linkages. Each respondent could check more than one category.

As already mentioned, tenants do not need internal R&D capabilities to become involved in cooperations with the local university. For instance, only 7 out of 13 Dutch tenants having in-house R&D-capabilities are involved in collaborative R&D with the local university. Thus, 5 Dutch respondents (see table 5) without internal R&D do have collaborative R&D with the local university.

Type of linkage	Belgium (n=68)	Netherlands (n=41)
Collaborative R&D	17	12
Academic consulting	14	12
Service (e.g. routine tests and analyses)	8	4
Informal contacts	18	16
Other	12	12

Table 5: Number of respondents per type of linkage

"Other" linkages include such activities as: organizing seminars together with a university department; the founder of the company was a student or researcher at the university; the company

is a university supplier (e.g. medical equipment); key scientists of the tenant firm lecture at the university; the tenant company supports the university's computer facilities etc. In many of those instances, the university benefits more from the presence of the tenant company than vice versa. This finding was also reported by Sirbu et al. (1976).

To conclude, although a majority of respondents has some type of linkage with the local university, only a minority of these linkages involves collaborative R&D. It is interesting to quote the results from the British study here: "The most obvious and perhaps surprising observation is how apparently similar off-park firms' responses were to those of on-park firms. This is particularly clear in the R&D and personnel links. Park-based firms clearly place a greater emphasis on informal contacts with academics. In the more formal links such as the employment of academics, sponsoring trials, student project links and the employment of graduates, off-park firms have an equal or greater number of links." (Monck et al., 1988). Although our research at this phase was only intended to get an overall impression of the R&D environment on Belgian and Dutch science parks, and thus did not include a control group of off-park firms, the similarity between our findings and the extensive British study is striking and certainly adds to the external validity of both studies' results.

4.5.2. Labor supply

Labor supply was one of the critical factors in the Dorfman study (1983). Table 6 summarizes the number of local university graduates employed at the respondents' facilities.

The total number of local university graduates employed at Belgian respondents is 179 (total employment=3856, i.e. 4.6%). In the Dutch case we find 61 local university graduates (total employment=480, i.e. 12.7%). Given the scope of this preliminary survey, comparison with off-park firms is impossible. We also lack information on the relative number of graduates from other universities employed at the respondents. This makes interpretation of table 6 a little ambiguous.

However, the fact that more than half of the respondents do not employ local university graduates at all questions the importance of the labor supply factor within the micro-environmant of the parks. This finding reminds us of Sirbu's suggestion that science park tenants recruit on a nation-wide basis (cfr. supra).

Number of local university graduates employed	Number of respondents Belgium (n=68)	Netherlands (n=41)
0	35	24
1-5	25	15
6-10	2	2
11-15	4	0
20	1	0
30	1	0

Table 6: Employment of local university graduates

Another potential advantage of a science park location is the easy access of tenants' employees to continuing education programs at the local university. Ten Dutch respondents (24%) and 18 Belgian respondents (26%) acknowledge to make use of this opportunity. This situation may well be subject to change in coming years as more and more universities start offering post-experience courses. However, at the moment, continuing education appears to be a rather limited phenomenon. Moreover, in many instances it is confined to employees enrolling in management and business oriented courses at the nearby university, as appeared from interviews with firms who made use of this opportunity.

4.5.3. R&D projects

The 13 Dutch and 39 Belgian respondents who mentioned the presence of internal R&D capabilities, also specified the actual number of R&D projects in progress, the fraction of those

projects carried out without external collaboration, and the distribution of projects involving external partners. Table 7 summarizes some of the results.

	Belgium (n=39*)	Netherlands (n=13)
Total number of projects in progress	321	65
Fraction <u>not</u> involving external partners	168 (52%)	25 (38%)
Fraction involving external partners	153 (48%)	40 (62%)
-local university as partner	35	12
-other science park partner	3	2

<u>Table 7</u>: Number of internal/external R&D projects at respondents having internal R&D-capabilities (*: of the 39 Belgian respondents, 2 did not specify the number of ongoing projects)

Although formal, external R&D linkages are important, they are not really biased towards the local science park environment. In Belgium, 38 (out of 153, 25%) R&D projects were directed towards local science park organizations. For the Dutch respondents, this amounted to 35%, or 14 projects. Of course, this does not yet tell us very much about the characteristics of the projects (content, duration, degree of innovativeness, etc.). But we must not forget that over half of our respondents did not have internal R&D-activities. We are confident that the respondents without internal R&D who are involved in collaborative projects together with the local university will not alter the obtained percentages much. We arrive at this assumption by looking at the individual respondents. The respondents in table 7 are without doubt the most important R&D-oriented

tenants on the sites studied. The respondents who have no internal R&D capabilities, though are involved with the local university, are all very small and production or marketing oriented.

The large number of projects (321) going on at Belgian science park firms is explained by the fact that a number of multinational companies have located their research centers there. Furthermore, both for Belgium and the Netherlands, we classified the science park tenants into 3 groups: (1) multinational firms -- (2) spin-offs -- (3) firms belonging to neither of those two groups (i.e. national, well-established companies). For both countries, almost no statistical significant differences could be found among the three groups as far as the different kinds of projects are concerned (table 8), although it is obvious that small spin-off companies have on average less R&D projects going on than the laboratories of large multinational companies or even long-established local companies. The only significant difference appeared between the numbers of collaborative projects for Dutch multinational and Dutch spin-off firms (Mean difference=5.3, Scheffé F-test=4.112, significant at 95%), though the small number of Dutch multinationals undoubtedly questions the validity of this result.

Table 7 further demonstrates that collaborative R&D efforts are not confined to a physical locus. The collaborative R&D-efforts reported in table 7 do not only have a national dimension (as well in Belgium as in the Netherlands, a lot of respondents having collaborations with the local university also have collaborations with a major part of the nations' other universities), but they take on international dimensions as well (e.g. projects together with other European and even U.S. universities).

Altogether, the small firms reporting collaborative R&D have a stronger bias towards the local university. For instance, for the 4 Belgian spin-offs reporting in-house research, we found that all the collaborative projects were carried out together with the local science park university. For the 5 Dutch spin-offs doing in-house R&D, 67% of the projects carried out in collaboration with an external partner had the local university involved. Thus, this type of company may actually

gain easier access to the relevant professional community by locating near a particular university. But even here, Macdonald (1987) warns us: "The notion that any single university department contains even all the technical information required by a high-technology firm, while evident in much of the justification given for science parks, would alarm most academics. Only a weak department can pretend to be self-contained: the strongest department is more likely to be but a node of an academic information network to which high-technology firms may seek access."

Company type	Belgium (N=37)		Netherlands (N=13)	
	All projects		All projects	
	N	Mean	N	Mean
(1) Multinational firms	22	19.8	2	6.5
(2) Spin-offs	4	2.8	5	4.2
(3) Other firms	11	6.6	6	5.2
	F=.748 (df1=2,df2=34), p=.481		F=.457 (df1=2,df2=10), p=.646	
	Collaborative projects		Collaborative projects	
	N	Mean	N	Mean
(1) Multinational firms	22	6	2	6.5
(2) Spin-offs	4	.25	5	1.2
(3) Other firms	11	1.1	6	3.5
	F=1.582 (df1=2,df2=34), p=.2203		F=4.316 (df1=2,df2=10), p=.0445	

Table 8: Comparison among different firm types for all projects and for collaborative projects

Finally, we made an attempt at classifying the projects into 4 different categories: basic research, applied research, development and technical service. This classification was based on Allen, Lee and Tushman's grouping of tasks along the R&D activity spectrum (1980). Of the 65 Dutch R&D projects, 55 could be classified as follows: 6 basic research -- 26 applied research -- 22 development -- 1 technical service. For the Belgian respondents, 310 projects could be classified: 19 basic research -- 56 applied research -- 129 development -- 106 technical service. For both countries, though, differences in the distribution along the activity spectrum could be found when comparing projects carried out in-house with projects involving external collaborations. As well in Belgium as in the Netherlands, about 40% of the 'research projects' (basic and applied research combined) were carried out internally, while about 60% of this group of projects was carried out together with an external partner. The comparison for development and technical service projects combined was a mirror image of the previous finding: about 60% of these 'non-research' projects were carried out internally, while only about 40% involved external partners.

5. Discussion and conclusions

This study was an attempt to provide some insight into the potential role of science parks in the process of technological innovation. An empirical inquiry into potential advantages and misconceptions related to science and technology parks seemed desirable, since the number of science parks keeps growing and since they are often claimed to offer a competitive advantage to tenant firms in terms of access to the professional community relevant to the firm. One key conclusion is that, despite this belief, our findings and the findings of similar foreign studies question the degree to which this really happens. Moreover, as has been correctly argued by Macdonald, the university affiliated with the science park is at best one node in the global professional community of interest to the high-technology firm. We firmly support the hypothesis that scientific and technological developments occur within the context of broader professional

communities. These communities are global in nature, encompassing researchers in organizations in the private as well as in the public sector. Warnings that a science park can create at most a "miniature network" among tenants is highly relevant in this respect and seems to be borne out by our findings on collaborative R&D at science park firms.

This leads the another remark. Given the ambiguous performance of most science parks, we believe it is time for a clear assessment of their mission. The findings on the oldest Belgian parks clearly demonstrate that they have been successful in attracting tenant firms. In terms of fostering extra-organizational R&D linkages the situation looks a little different, however. There do exist linkages towards the local science park environment, though they are rather sparse. Nowadays we observe a trend where each university believes an affiliated science park is an absolute necessity in order to become an accepted player in the newly emerging arena of entrepreneurial science. We hope that this discussion has shown that a science park is not necessary the most effective way to become involved in industrial science and technology. A multitude of other mechanisms exist. At the same time, the discussion of the "role models" (Silicon Valley, Route 128 and Cambridge-UK) places their spontaneous development in sharp contrast with the artificial "push" experienced on most science parks. In these "role models", science parks were consequences rather than causes of regional technological development.

Finally, this discussion leads to the much broader issue of the process of the emergence of new technologies. The previous sections on science parks and their presumed role in the process of technological development clearly show an urgent need for a better understanding of the nature of this process. As long as we do not have a well articulated theory of this process, policies to stimulate the development of new technologies are likely to be prone to misconceptions.

Recently it has been proposed that technological development appears within the context of R&D communities (Rappa and Debackere, 1989). The R&D community is defined as a group of individuals, composed of scientists and engineers, who are committed to solving a set of

interrelated scientific and technological problems, who may be organizationally and geographically dispersed, and who communicate in some way with each other. Members of those R&D communities appear to form worldwide information networks, through which relevant technological information flows between organizations and individuals belonging to the network.

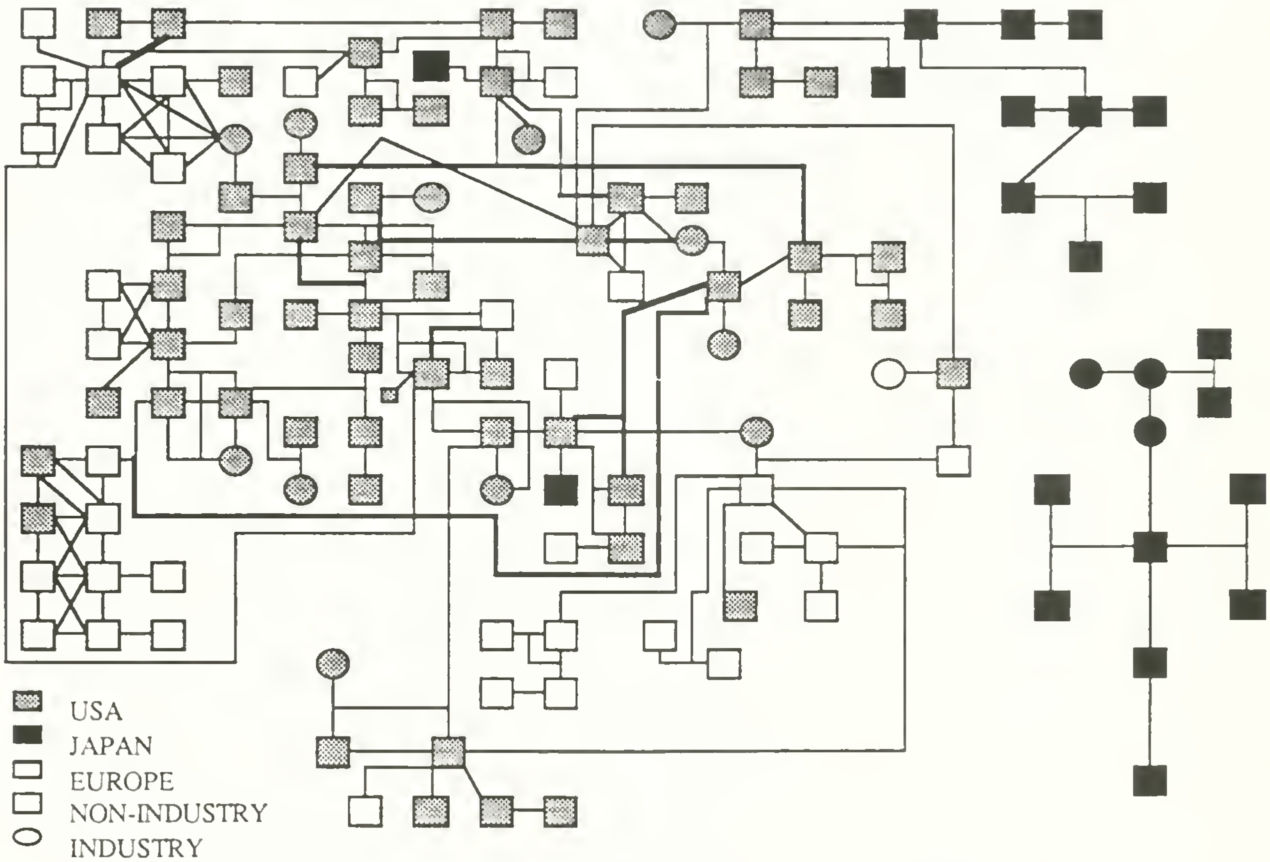

Figure : Interorganizational grapevine for the neural network R&D community

Clearly, for scholars and managers who try to understand how one might gain access to a network of technical information, understanding the dynamics behind R&D communities is imperative. Instead of focusing on the "miniature" networks which form around science parks, the broader professional information network obviously deserves primary attention. Moreover, by studying R&D communities, we may gain insight in how the conduct of many researchers,

dispersed as they may be among many organizations, influences the development of new technologies. By way of example, the figure shows the worldwide "grapevine" which has developed over two decades among neural network researchers. This grapevine enables one to see where the action is on the research front for this particular technology. A science or technology park can presumably be of little influence in gaining access to this broader network. Other actions, such as allowing one's researchers to become actively involved in the network, are undoubtedly more efficient.

Understanding the role of R&D communities in the emergence of new technologies, how they shape them, and how they choose and determine the direction technological trajectories take, are then major issues on our present research agenda. We hope to inform you about these issues in the near future.

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